Sprinkler Irrigation Spray Temperatures

C. H. Pair, J. L. Wright and M. E. Jensen
Fellow ASAE — Member ASAE

THE temperature of irrigation water may vary from zero, where the source is a melting snowbank, to near 90 C where the source is a hot spring or well such as those along the Snake River. Water heated by nuclear reactors may provide hot water for irrigation in the future. Water of these extreme temperatures is frequently used in sprinkler irrigation. It is important to crop production and management to know the temperature of the water as it comes in contact with the crop or soil because of the effect of temperature on germination of seed; development of fruit, vegetables, and other crops; frost protection, and crop-cooling operations.

Theoretically, the water droplet passing through the air after leaving the sprinkler nozzle should approach the wet-bulb temperature of the air. Frost and Schwalen (2)*, in accounting for spray loss from sprinklers, assumed that the temperature of each droplet is reduced to wet-bulb temperature by the time it reaches the ground surface. The wet-bulb temperature is defined as the temperature that air assumes when water at the current temperature is introduced gradually and evaporated adiabatically at constant pressure until the air is saturated. Wet-bulb temperature is measured by a ventilated thermometer, the bulb of which is covered with a wet piece of cloth. The theory of psychrometric wet-bulb temperature is discussed in many references dealing with the moisture variable of the air (1, 3, 4, and 6).

The temperature of the water in a sprinkler spray is changed primarily by evaporation, conduction, and, to a much lesser extent, by radiation of the heat to or from the air. When the initial water temperature is higher than air temperature, the droplet temperature will decrease as it passes through the air by both evaporative cooling and the loss of heat by molecular collisions. After cooling to air temperature, the

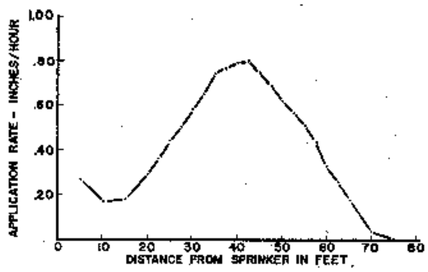

FIG. 1 Water-distribution pattern using sprinkler hood: nozzle size, ⅜-in. diameter; nozzle pressure, 75 psi.

droplet continues to cool by evaporative cooling to the wet-bulb temperature, if it remains in the air long enough. When the initial water temperature is below the wet-bulb temperature, the droplet will be warmed as it passes through the air by molecular collision until it reaches the wet-bulb temperature. The droplet temperature will not rise above this because of evaporative cooling. In either case, the temperature of the water droplet as it strikes the foliage or soil is primarily determined by the relative rate at which heat is transferred to and from the droplet by molecular collisions and evaporation or condensation of water.

Though the wet-bulb temperature that the water droplet will approach can be predicted from psychrometric theory, the rate at which this temperature will be attained is much more difficult to establish theoretically. The rate of cooling or warming depends on the difference between the wet-bulb and dry-bulb temperatures of the air, the volume and shape of the droplet, and the velocity of the droplet relative to the air through which it is passing.

Studies were conducted at the Snake River Conservation Research Center, Kimberly, Idaho, to determine the temperature of the water spray from an agricultural irrigation sprinkler as it reached the ground level when waters of various temperatures were used.

Procedure

A sprinkler with a ⅜-in. nozzle was operated at 75 psi. The sprinkler head was mounted in a Tovey hood (7), which permitted the jet to discharge into the air during a portion of the sprinkler rotation. Pressure was supplied to the water by a gasoline-engine-driven centrifugal pump. The sprinkler discharge was 35 gpm. A typical distribution pattern for the half-circle operation used in the temperature test is shown in Fig. 1.

A stock tank mounted above ground was used for water storage for each test. Tests were conducted with water in the supply tank maintained at temperatures of 35, 44, 51, 67, 95, 129, 146, 174, and 194 F. The water was heated with a gas burner or cooled with blocks of ice before each test to obtain the desired temperature.

Catch cans were placed 10, 22½, 40, 50, and 60 ft from the sprinkler nozzle. These cans consisted of a polystyrene cup inside a cardboard quart oil can. A funnel over the mouth of the can concentrated the spray into a stream which flowed over a copper constantan thermocouple suspended just below the funnel. A second thermocouple was mounted in the bottom of the polystyrene cup to monitor the temperature of the accumulated water from the funnel. The thermocouples were made with No. 36 gage wire, the small mass of which allowed detection of very small changes in temperature. The catch can and thermocouple were placed in a one-gal paper icecream carton painted white. (See Fig. 2 for details of spray catch cans.) Shade screens were provided to shade the catch cans from direct sunlight (Fig. 3). The output from the thermocouples was recorded with a 12-point recorder every 36 sec during each test period. Measurements were made in September 1965 and September 1967.

Results and Discussion

The results of this study indicate that when applying water by sprinkler irrigation, the temperature of the water striking plant surfaces will be essentially that of wet-bulb temperature regardless of the initial water temperature (Table 1). The temperature of the water droplets increased to within 1.8 C (3 F) of wet-bulb temperature when using water near freezing, and cooled to within 3.4 C (6 F) of wet-bulb temperature when using water heated to near boiling.

The tests demonstrated that water temperature increased as much as 8 C (15 F) when it was below wet-bulb temperature, and cooled as much as 75 C (135 F) when it was initially above wet-bulb temperature. Water temperature varied little with distance from the sprinkler. The smaller drops

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The authors—C. H. PAIR, J. L. WRIGHT and MARVIN E. JENSEN—are, respectively, research engineer (irrigation), research soil scientist, and director Snake River Conservation Research Center, Kimberly, Idaho.

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* Numbers in parentheses refer to the appended references.

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travelled a shorter distance, but, because of size, their temperatures approached wet-bulb equilibrium more rapidly. The larger drops travelled a greater distance and thus had more opportunity to approach wet-bulb temperature.

Some crops may be sensitive to large temperature changes at critical stages of growth. Thus, even though air and water temperatures may be near 35 C, the temperature of the water striking the foliage may be considerably below this value. These studies also demonstrate that hot water can be used for sprinkler irrigation of crops without much concern for the effects of high water temperatures. However, water from natural hot springs may contain soluble materials that may be harmful to plants and soil. Also, when natural hot waters are cooled, some salts may precipitate.

TABLE 1. SPRINKLER SPRAY TEMPERATURES AS INFLUENCED BY NOZZLE WATER TEMPERATURE AND DISTANCE FROM SPRINKLER

Nozzle water temperature		Air temperatures				Sprinkler spray temperatures					
		Dry bulb		Wet bulb		At 10 ft from nozzle		At 22.5 ft from nozzle		At 40 ft from nozzle	
C	F	C	F	C	F	C	F	C	F	C	F
1.7	35	16.4	61.5	11.1	52	9.9	50	9.3	49	9.5	49
6.9	44	16.4	61.5	11.1	52	9.8	50	9.3	49	9.8	50
10.5	51	24.4	76	12.2	54	13.6	56	12.6	55	12.0	54
19.6	67	18.9	66	11.7	53	12.9	55	12.7	55	12.3	54
34.8	95	13.9	57	7.3	45	8.7	48	8.8	48	9.2	48
53.9	129	18.9	66	11.7	53	12.8	55	12.6	55	13.3	56
63.5	146	18.9	66	11.7	53	12.3	54	12.7	55	13.2	56
79.0	174	22.2	72	11.7	53	14.6	58	14.4	58	14.1	57
90.0	194	22.2	72	11.7	53	14.5	58	15.1	59	14.8	59

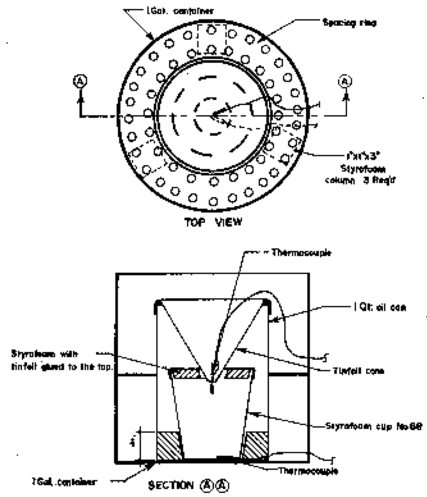

FIG. 2 Spray catch-can construction.

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FIG. 3 Layout of equipment for measuring temperature of sprinkler spray.